

Nanoconverters for Powering Nanodevices

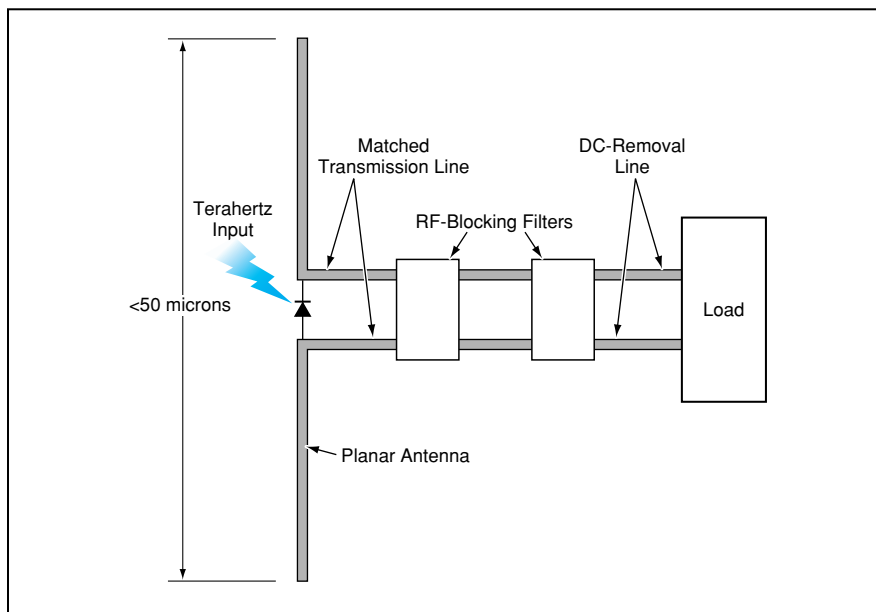
Power would be beamed at terahertz frequencies, using microscopic transmitting and receiving antennas.

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Proposed integrated-circuit modules called "nanoconverters" would derive DC power from impinging electromagnetic beams having frequencies in the terahertz range. Nanoconverters are composed of microscopic antennas and diodes (see Figure 1) resembling rectennas that have been developed to perform the same function at frequencies in the gigahertz range. The submillimeter wavelength nanoconverters would make it possible to incorporate the antenna elements and diodes on structures much smaller than those of prior rectennas, thereby opening up opportunities for noncontact transmission of power to a variety of microelectronic devices, including surgically implanted medical devices and untethered microscopic robots.

The basic concept of radio beaming of electric power through space without the use of wires was explored before World War II and has been used at microwave frequencies. Novel aspects of the terahertz nanoconverter include:

1. Fully integrated monolithic rectennas at submillimeter dimensions,
2. Direct integration auto microrobots and devices,
3. Fairly high radio frequency (RF) to DC conversion efficiency with focusing optics,
4. Greater penetration in biomaterials and many plastics than infrared (IR) or visible wavelengths,
5. Negligible tissue damage due to non-



An Antenna-and-Diode Combination (a rectenna) would convert power from an impinging terahertz radio beam to DC. The transmission line and RF filter confine the terahertz signal to the diode and allow DC to be removed.

resonant frequencies and low beam density, and
6. Fully integrated packages for direct RF in DC out.

Techniques, processes, and equipment needed for manufacturing circuitry with dimensions comparable to those of nanoconverters have already been developed for manufacturing GaAs-based sen-

sors and sources at the frequencies. The nanoconverters could be used to remotely transmit power to microdevices in hostile environments or through smoke and dust.

This work was done by Peter Siegel of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP [see page 1].
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MOS Circuitry Would Detect Low-Energy Charged Particles

Conversion from ions to electrons, and photons, would not be necessary.

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Metal oxide semiconductor (MOS) circuits for measuring spatially varying intensities of beams of low-energy charged particles have been developed. These circuits are intended especially for use in measuring fluxes of ions with spatial resolution along the focal planes of mass spectrometers. Unlike prior mass-spectrometer focal-plane detectors, these MOS circuits would not be based on ion-induced generation of electrons, and photons; instead, they would be based on direct detection of the electric charges of the ions. Hence, there would be no need for microchannel plates (for ion-to-electron conversion), phosphors (for electron-to-photon conversion), and photodetectors (for final

detection) — components that degrade spatial resolution and contribute to complexity and size.

The developmental circuits are based on linear arrays of charge-coupled devices (CCDs) with associated readout circuitry (see figure). They resemble linear CCD photodetector arrays, except that instead of a photodetector, each pixel contains a capacitive charge sensor. The capacitor in each sensor comprises two electrodes (typically made of aluminum) separated by a layer of insulating material. The exposed electrode captures ions and accumulates their electric charges during signal-integration periods.

The CCD array is of a standard three-

phase type. The array circuitry includes a shift register and a charge-mode input structure denoted a "fill-and-spill" structure. This structure provides the coupling through which the charge accumulated in each capacitive sensor gives rise to a packet of signal charge in the shift register. The fill-and-spill structure has previously been shown to keep the nonlinear component of response below -100 dB, with negligible offset. An ancillary benefit of the fill-and-spill design is elimination of a noise component proportional to kTC (where k is Boltzmann's constant, T is absolute temperature, and C is capacitance) that would be present if the charge-storage wells in the array were to be